# CONVERSION OF "WHOLE" AND "HEADLESS" WEIGHTS IN COMMERCIAL GULF OF MEXICO SHRIMPS

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## ABSTRACT

Shrimp landing statistics provided by the Gulf coast fishing industry are now published by the Bureau of Commercial Fisheries in terms of "headless" (or "heads-off") weight units. Reliable factors are needed by statistical agents to convert landings of "whole" (or "heads-on") shrimp to headless units, and by biologists and others to reconvert the published statistics to whole-shrimp units.

Measurements of whole and corresponding headless weights permitted estimation of weight conversion factors for five of the most common Gulf of Mexico Penaeidae. Factor variation due to area, season, and sex proved negligible from a practical standpoint. Differences between species were generally significant while all factors departed significantly from the single factor heretofore employed for converting weights in all species. Equations and factors for predicting whole or headless weights are given for the brown, white, pink, and rock shrimps, and the seabob. Weight conversion nomographs foı the brown, pink, and white shrimps are also provided.

Statistics describing the extensive commercial fisheries for Gulf of Mexico shrimps (Penaeidae) are routinely collected by the Branch of Statistics, Bureau of Commercial Fisheries. These are published monthly in tables entitled *Gulf Coast Shrimp Catch by Area, Depth, Variety, and Size*. They include corresponding information on number of fishing trips by commercial trawlers, the total amount of time spent fishing, and the dockside value of total landings. Such data have wide application in studies dealing with the conservation of shrimp stocks and the economic condition of fisheries they support.

As a convenience to the fishing industry, commercial catch statistics are tabulated according to weight in terms of "headless" (or "heads-off") shrimp. Biologists, however, find such notation somewhat unwieldy. Thinking of what shrimp harvests represent in terms of the proportion of the *total* shrimp biomass removed, they must, therefore, resort to devices which enable them to convert headless back to "whole" (or "heads-on") units. A single conversion factor which has served this function for many years within the shrimp industry itself, was incorporated

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into the present statistical survey as an aid to whoever might find it necessary to convert the catch figures reported. As can best be ascertained, this factor, 1.680, was originally arrived at by calculating the ratio between a standard barrel (210 pounds) of whole shrimp and its yield of headless shrimp. We are not certain which species of shrimp was involved in this initial calculation, but the resulting value has since been adopted for use with the four major kinds, namely, the brown shrimp, *Penaeus aztecus;* pink shrimp, *P. duorarum;* white shrimp, *P. setiferus;* and seabob, *Xiphopeneus krøyeri.* Conversely, its reciprocal, 0.595, permits shrimp buyers and statistical agents to convert heads-on landings to heads-off units. Hence for a commercial species of any size, about 125 pounds of heads-off shrimp may ostensibly be expected from every standard barrel of heads-on shrimp. Because these complementary factors are employed in business transactions, especially in areas where heads-on landings of small shrimp predominate, their accuracy is of vital concern.

Since 1956, when the present statistical survey was inaugurated, questions have arisen periodically as to the statistical reliability of the above-mentioned factors. Recent studies of conditions in Gulf of Mexico shrimp stocks as revealed by commercial fishery statistics reemphasized the need to give these factors the appraisal that many have felt has been long overdue. In connection with population studies underway at various points along the Gulf coast, shrimp measurement data of several kinds have accumulated. These include weights of the whole and corresponding headless portions of shrimp representing the major commercial species. For all species, measurements sufficient to provide quite precise estimates of the whole-headless (and vice versa) ratio were found to be available. For some, additional data were secured so that the ratio's variability according to area, season, and sex could be determined.

## MATERIAL AND METHODS

Brown, pink, and white shrimp of all sizes from the smallest juvenile to the largest adult are treated in the following analysis. Only medium-size and a few large adults represent the seabob and rock shrimp, *Sicyonia brevirostris,* a commercially potential but not as yet utilized species. All specimens except those of pink shrimp came from the east Texas-western Louisiana area. The pink shrimp were taken in Biscayne Bay (Florida) and the Gulf of Mexico just north of the Dry Tortugas.

Individuals were secured by sampling commercial bait shrimp (inshore) catches, by sampling commercial (offshore) landings prior to their processing at dockside plants, and from biological samples taken by research vessels operating on inshore waters and at sea. After excess moisture was removed, weights of individual whole and corresponding beheaded shrimp were recorded to the nearest one-tenth gram in most cases, and to the nearest one-hundredth gram in the remainder. Beheading proceeded in as uniform a manner as possible, using techniques commonly employed in the shrimp industry.

## RESULTS AND DISCUSSION

If a straight line best characterizes the relationship between two variables, then the method of least squares provides the most efficient estimate of their mean ratio, commonly referred to as the regression coefficient. For each species, inspection of paired data (whole and headless weights) indicated that a straight-line relationship did prevail, this being subsequently confirmed by means of appropriate statistical tests. Employing the least squares method, I fitted straight lines to the data and obtained the desired estimates. These, together with the corresponding prediction equations, are summarized in table 1.

Actually, two regressions of the form $Y = \underline{A} + \underline{B}X$ are called for under the present circumstances, depending upon which conversion factor (or regression coefficient, $\underline{B}$) is of interest. Assuming that both factors, the one relating headless to whole weight, and the one relating whole to headless weight, are equally useful, the regressions of headless on whole weight (Y on X) and whole on headless weight (X on Y) were computed. Theoretically, if "sampling" error were nil and the paired variates perfectly correlated, the coefficient of the one regression should equal the reciprocal of the coefficient of the other, and vice versa. Examination of the plots and subsequent fitting of the regressions revealed that, in the case of the brown, pink, and white shrimp, the data did in fact very nearly meet these requirements. The error proved so negligible and the variates so closely correlated that both regressions merged as one. This "common" regression is depicted for the brown, pink, and white shrimp respectively, in figures 1-3, which are presented merely as devices (nomographs) for graphic conversion. Observe that they permit (1) simple weight conversion in individual shrimp, (2) conversion from simple weight to corresponding number-per-pound units and

Table 1.--Prediction equations and component factors relating headless to whole (Y on X) and whole to headless (X on Y) weights in five common penaeid shrimps.

$\hat{Y}$ = predicted weight of headless shrimp; $\hat{X}$ = predicted weight of corresponding whole shrimp

| Species | Sample size N (1) | Prediction equations: Assuming $\underline{A} \neq 0$ (2) | Prediction equations: Assuming $\underline{A} = 0$ (3) | Conversion factors: Assuming $\underline{A} \neq 0$ (4) | Conversion factors: Assuming $\underline{A} = 0$ (5) |
|---|---|---|---|---|---|
| Brown shrimp | 267 | $\hat{Y} = 0.616X + 0.120$ | $\hat{Y} = 0.620X$ | $0.616 \pm 0.005$ | $0.620 \pm 0.004$ |
| | | $\hat{X} = 1.617Y - 0.153$ | $\hat{X} = 1.610Y$ | $1.617 \pm 0.115$ | $1.610 \pm 0.010$ |
| Pink shrimp | 1617 | $\hat{Y} = 0.614X + 0.315$ | $\hat{Y} = 0.625X$ | $0.614 \pm 0.003$ | $0.625 \pm 0.002$ |
| | | $\hat{X} = 1.614Y - 0.342$ | $\hat{X} = 1.599Y$ | $1.614 \pm 0.024$ | $1.599 \pm 0.005$ |
| White shrimp | 1306 | $\hat{Y} = 0.644X + 0.011$ | $\hat{Y} = 0.648X$ | $0.644 \pm 0.004$ | $0.648 \pm 0.002$ |
| | | $\hat{X} = 1.534Y - 0.081$ | $\hat{X} = 1.543Y$ | $1.534 \pm 0.090$ | $1.543 \pm 0.005$ |
| Seabob | 365 | $\hat{Y} = 0.631X + 0.029$ | $\hat{Y} = 0.652X$ | $0.631 \pm 0.010$ | $0.652 \pm 0.006$ |
| | | $\hat{X} = 1.552Y - 0.017$ | $\hat{X} = 1.533Y$ | $1.552 \pm 0.024$ | $1.533 \pm 0.009$ |
| Rock shrimp | 477 | $\hat{Y} = 0.569X + 0.565$ | $\hat{Y} = 0.601X$ | $0.569 \pm 0.009$ | $0.601 \pm 0.003$ |
| | | $\hat{X} = 1.709Y - 0.530$ | $\hat{X} = 1.659Y$ | $1.709 \pm 0.025$ | $1.659 \pm 0.007$ |

vice versa, and (3) conversion on a number-per-pound basis alone.

To use figures 1-3 for purposes of rough conversion, proceed as follows for each of the indicated cases:

1. Determine the predicted weight of a headless shrimp by simply reading upward from the whole weight on the lower scale to the diagonal line, and then across to the corresponding headless weight on the left-hand scale. Determine the predicted weight of a whole shrimp from its corresponding headless weight by reversing the process. Mathematically, the conversion proceeds as follows: For example, assume a headless brown shrimp weighs 27.42 grams and we wish to determine what its whole weight was. Using the second equation given in the lower righthand corner of figure 1 (also in column 2 of table 1),

$$\text{Predicted whole weight} (\hat{X}) = 1.617(27.42) - 0.153 = 44.18 \text{ grams.}$$

2. Determine the approximate number comprising 1 pound of headless or whole shrimp, in which every individual has the same specified weight, by reading directly from either the left- to right-hand scale, or from the lower to upper scale (figs. 1-3). Hence 1 pound of shrimp (any species) wherein each individual (headless or whole) weighs 50 grams would contain roughly 9 specimens; 1 pound of shrimp in which every one weighs 30 grams would contain about 15 specimens. The reverse procedure enables conversion from number-per-pound to individual weight units. In addition, the numbers per pound of headless shrimp yielded by uniformly sized whole shrimp of a specified weight are obtained by reading from the lower scale to the diagonal and thence to the right-hand scale. Thus whole white shrimp (fig. 3) weighing 80 grams (3 oz.) yield headless shrimp of a size such that nine will weigh 1 pound. In the same manner, conversion from uniform headless weight to corresponding whole-shrimp-per-pound units is made by proceeding from the left-hand scale to the diagonal, and then to the upper scale.

3. Determine in terms of number-per-pound units the yield of headless shrimp from the corresponding whole shrimp by simply reading down from the upper scale to the diagonal, and then across to the left-hand scale. For instance, pink shrimp

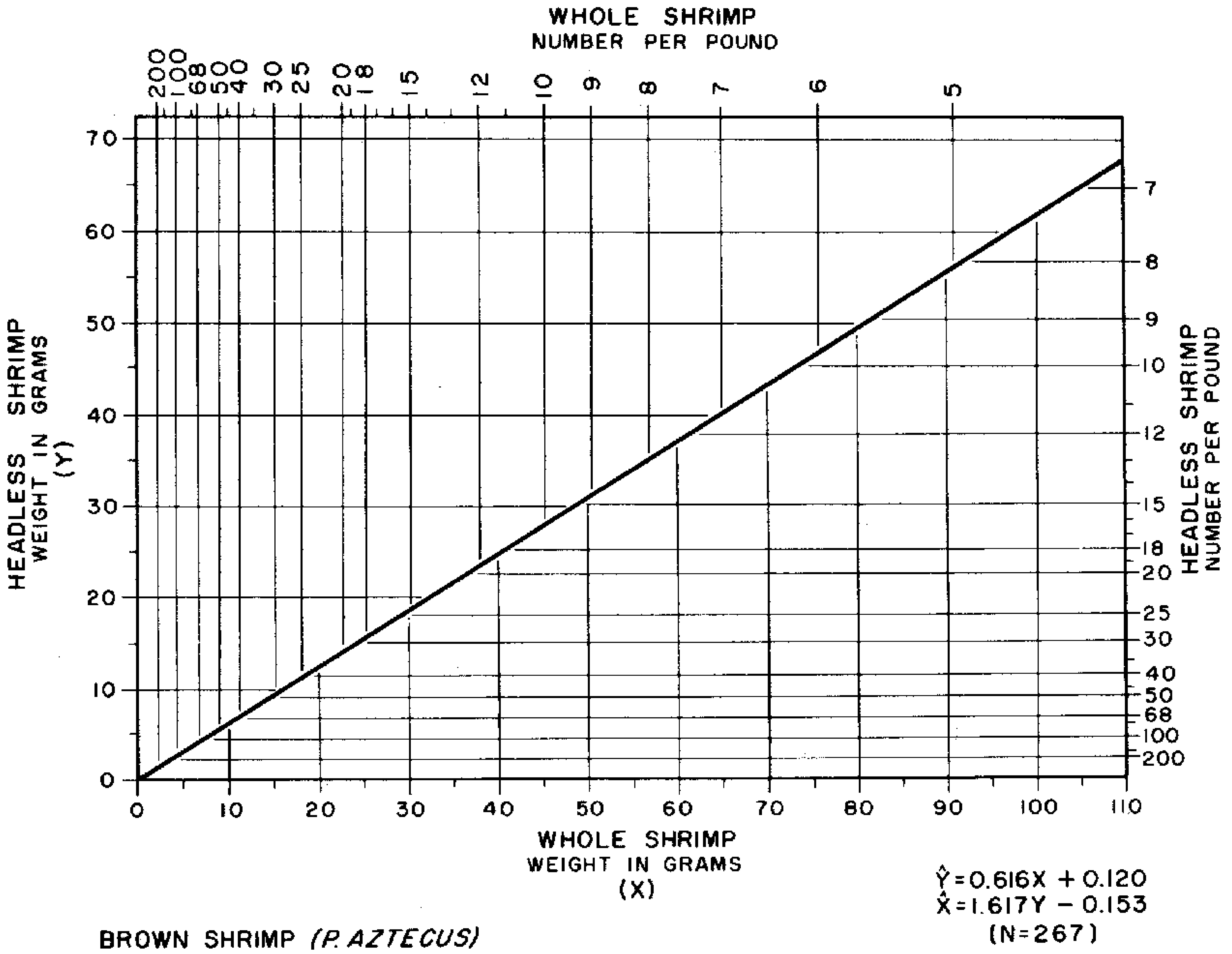


Figure 1.--Nomograph for conversion of weights and numbers of whole and headless brown shrimp.

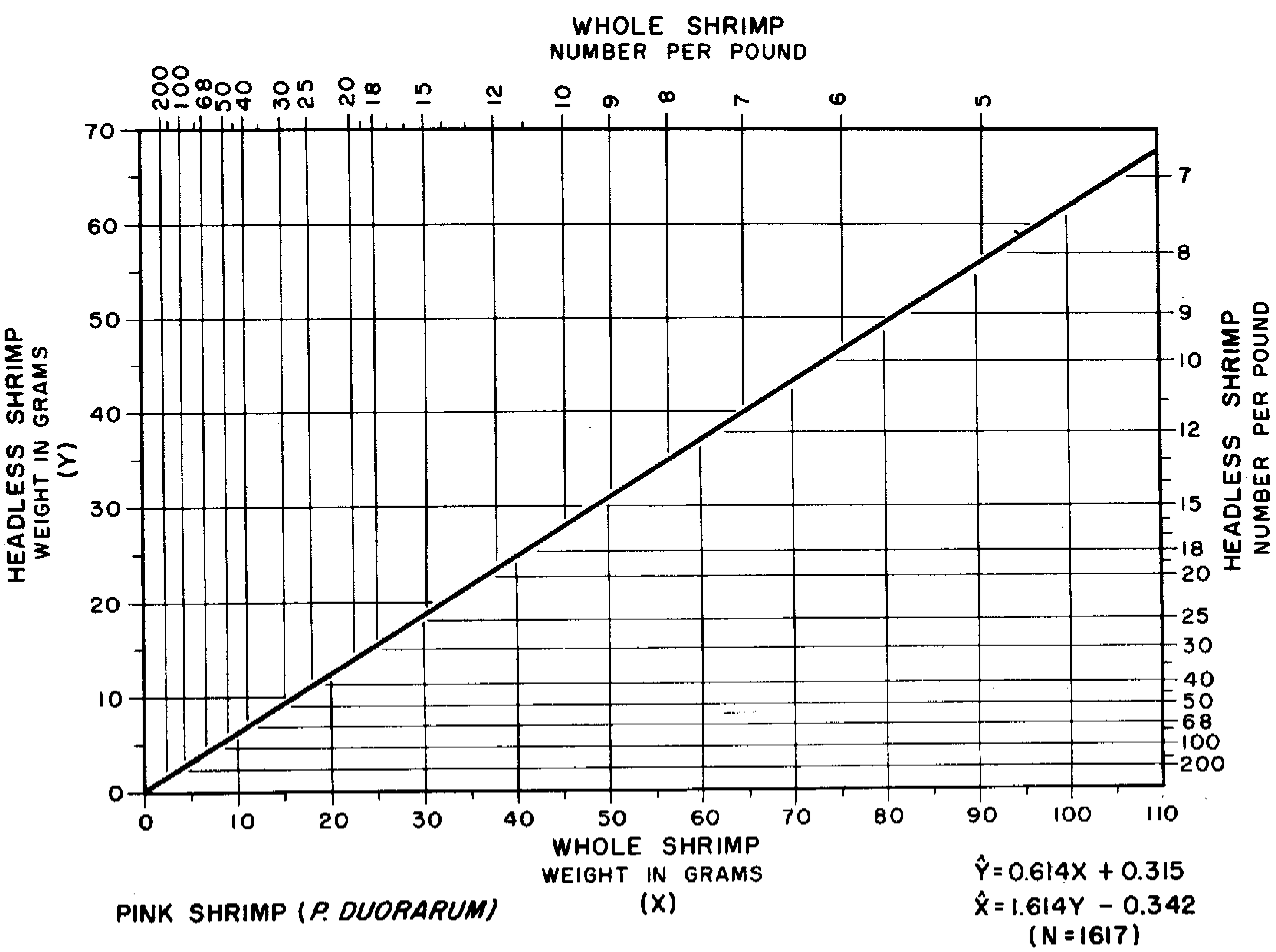


Figure 2.--Nomograph for conversion of weights and numbers of whole and headless pink shrimp.

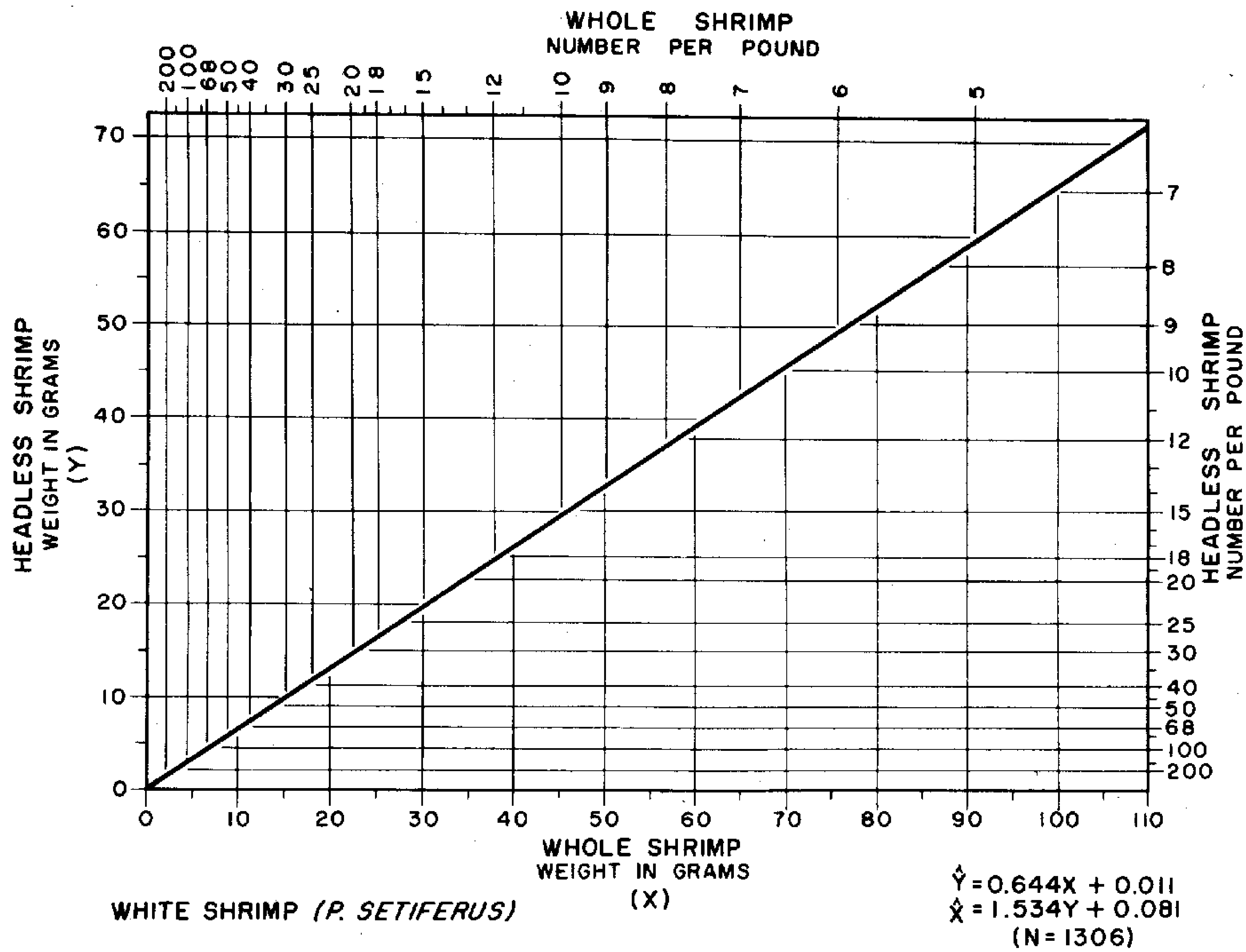


Figure 3.--Nomograph for conversion of weights and numbers of whole and headless white shrimp.

(fig. 2) of a uniform size such that 20 weigh 1 pound will yield headless shrimp of a size such that 32 will weigh the same.

The relative precision inherent in the equations given in the second column of table 1 and in the lower right hand corner of each graph can be exemplified by substituting some hypothetical data in those for white and brown shrimp. Appropriate calculations reveal that in the white shrimp (fig. 3), the headless weight of any individual whole shrimp may be estimated to within 1 gram with a confidence probability of 95 percent. Thus the estimated "tail" weight of a white shrimp weighing 40 grams in the round would be 25.77 ± 0.85 grams.

Due to an appreciably smaller sample size, conversion estimates in the brown shrimp (fig. 1) will be somewhat less precise than those in the white shrimp. Thus the estimated whole weight of a headless brown shrimp weighing 45 grams is 72.61 ± 1.95 grams, indicating precision of an order of magnitude still sufficiently small for all practical purposes. In general, the precision of conversion estimates for the first four species listed in table 1 will be such that estimates within 2 grams (most within 1 gram) will be the rule.

Obviously, the nomographs presented here only enable weight conversion in the case of individual shrimp, and would find greatest use by the fishery biologist faced, for example, with the problem of converting headless shrimp sampled for weight-frequency analysis to whole-shrimp units. The statistical agent, on the other hand, has a greater need for a simpler function which would allow him to convert large-volume landings in either direction and with reasonable precision.

In re-examining the prediction equations given in the second column of table 1, note the rather small values indicated for the equation parameter, A, the expression for either variable when the other is zero. Theoretically, A should always be zero since a shrimp without a head (or conversely, without a tail), regardless of stage in morphological development, is a physical impossibility. Parenthetically, "head" as used herein and throughout the shrimp industry, refers to the shrimp's cephalothorax, which does not become differentiable until the newly hatched larva transforms from a nauplius into a protozoea. This transformation involves development (extension) of the abdomen or "tail." In a sense, therefore, it would be possible at the earliest stages in a shrimp's life history to obtain a "whole" but no "headless" weight. Hence the true regression of headless on whole weight (Y on X) should contain a negative value for $\underline{A}$, that of whole on headless weight (X on Y) a positive value, the values in both cases being of a very low order of magnitude.

In the present case, the variation about the fitted line was unquestionably sufficient to result in a general departure in the sign of the observed $\underline{A}$ from that expected. Statistically, however, none of the observed $\underline{A}$'s in the eight regressions computed for the five species in table 1 differed significantly from zero. This suggested a simple proportional relationship between the two weight measurements and prompted refitting the regression lines through zero. The resulting equations are given in column 3 of table 1. Except for slight departures attributable to the rounding process, each member of the five pairs of factors tabulated is the reciprocal of the other. Observe also that these new factors do not differ greatly from the comparable values presented in column 2. They are preferred over the latter, however, and hence recommended for use in future computations involving mass conversion of catch weights in the case of each species represented. As an example of how these factors might be employed, assume a fisherman lands 987 pounds of whole brown shrimp (any or all sizes) but can obtain payment only on the basis of headless weight. Appropriate conversion would be made using the first equation given in column 3 of table 1. Hence

$$\text{Predicted headless weight } (\hat{Y}) = 0.620(987) = 612 \text{ pounds.}$$

Again, suppose the monthly landings of white shrimp from a particular area totaled 3,175,550 pounds in terms of headless weight, but that landings in terms of whole weight were needed to satisfy some requirement of a biological study utilizing such data. The appropriate conversion is made using the sixth equation in column 3 of table 1. Thus

$$\text{Predicted whole weight } (\hat{X}) \doteq 1.543(3{,}175{,}550) = 4{,}899{,}874 \text{ pounds.}$$

Factors for each species together with their 95 percent confidence limits are given in column 4 or 5 (table 1), according to the conditions for $\underline{A}$ under which they were calculated. Note that confidence limits under the assumption that $\underline{A} \neq 0$ are considerably narrower than under the alternate assumption. This follows from the fact that the slope (or regression coefficient) is restricted in its variation by the condition that the regression line pass through zero.

All of the foregoing estimates of factors relating headless to whole weights (and vice versa) in commercial shrimps constitute significant departures from the traditional 0.595 (and 1.680). Moreover, statistical comparison of regressions by means of covariance analysis indicated that regression coefficients (or conversion factors), on the whole, differed significantly between species, although those for the brown and pink shrimp on the one hand, and the white shrimp and seabob on the other, did not.

Further speculation as to factor differences between sex, geographic locale, and season (within species) prompted additional testing using the same statistical technique. Paired measurements for representatives of each sex were secured over a 5-month period for pink shrimp. The difference between sexes proved highly significant statistically, but in the case of the factor relating headless to whole weight (Y on X), the maximum deviation from the value given in columns 3 and 5 of table 1 was only two units in the second decimal place. In general, the headless weight (relative to the whole weight) of males slightly exceeded that of females. It is assumed that a similar difference would also hold for closely related species in other areas.

Factors calculated for pink shrimp sampled at two widely separated locations in Florida, namely, Biscayne Bay (Miami) and the Gulf of Mexico (north of Dry Tortugas), also differed statistically. Although sexes were about equally represented in the sample from each location, part of the difference could have been due to the fact that the sample from Dry Tortugas was largely obtained at a somewhat later season than that from Biscayne Bay. Again, the maximum deviation of the whole-to-headless factors derived for each area was only two units in the second decimal place from the average value given in column 5 of table 1, a departure not quite approaching practical significance.

Seasonal differences in whole-to-headless conversion factors were tested by using measurements of white shrimp sampled throughout the year in the east Texas coastal area. Based on data grouped arbitrarily under two seasons, March-August and September-February, they also proved statistically significant. Maximum deviation of seasonal factors from that computed using the combined data was again only two units in the second decimal place. The possible effects of inequitable representation of sexes could not be eliminated, however, due to the fact that sex was not determined for all specimens entering the samples.

There is the question whether single whole-to-headless (or vice versa) conversion factors computed from data combined over all seasons, etc., have maximum utility. Certainly they have a high degree of usefulness in the routine task of converting landing data, whereas too many factors, a set for every situation, would result in a loss of efficiency in data compilation without an appreciable gain in accuracy. Shrimp processors, on the other hand, recognize the fact that these factors are not stable and, particularly, that they do vary from season to season in a more or less predictable manner. Taking every advantage of this seasonal variation, the Louisiana shrimp canning industry, for example, employs in normal business transactions four whole-to-headless conversion factors (0.595 to 0.667), each being used in accordance with whatever appears to be the prevailing whole-headless relationship. Their use must assume, however, that the size of whole shrimp landed is uniform throughout each landing (since the conversion is on a number-per-pound basis) and that sexes are always equally represented. In the present study, lack of sufficiently refined data precluded an analysis that would assess the combined influence of season and sex on the relationship of interest. To make such an analysis would have necessitated a greatly expanded study, a need not clearly justified. For instance, the whole-to-headless factor, 0.646, obtained for the season September-February when inshore and offshore white shrimp landings in Louisiana reach a maximum, closely approximates that calculated from data combined over all seasons (table 1). The latter factor, 0.648, is equivalent to that resulting when conditions are such that a 210-pound barrel of whole shrimp yields 136 pounds of headless shrimp. Use of this factor at other seasons, despite the possibility of lower yields-per-barrel, would not, because of significantly smaller catches during these periods, create any appreciable difficulty from an economic standpoint--unless, of course, the seasonal price of shrimp fluctuated adversely.

## SUMMARY

Estimation of factors relating whole to headless weights in commercial Gulf of Mexico shrimps yielded values of 0.620 and 1.610 for brown shrimp; 0.625 and 1.599 for pink shrimp; 0.648 and 1.543 for white shrimp; 0.652 and 1.533 for seabobs; and 0.601 and 1.659 for rock shrimp. Subsequent analyses disclosed that their statistical reliability was such that in all cases, the coefficient of variation was less than 1 percent. It was revealed further (1) that the values for all species deviated significantly from those traditionally used heretofore, namely, 0.595 and 1.680; and (2) that although the factors of interest varied significantly from a statistical standpoint between sexes, areas, and seasons, departures from those values listed above were of little importance. The new values are recommended for use in procedures involving weight conversion of commercial shrimp landings. Nomographs which facilitate the conversion of individual whole or headless shrimp on a simple weight or number-per-pound basis are provided for the three most common species.

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